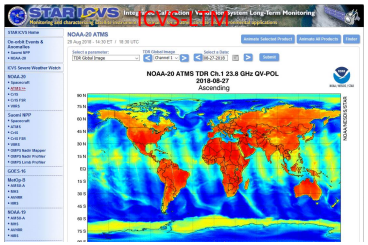
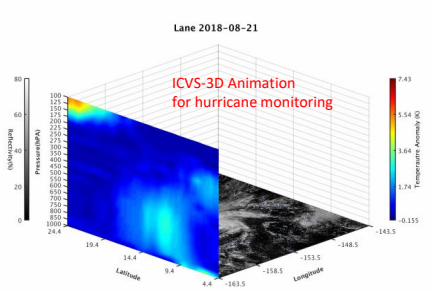
JPSS/STAR
Integrated Calibration/Validation System (ICVS): Status and Prospective

Banghua Yan*

NOAA/STAR/Satellite Calibration and Data Assimilation Branch



On behalf of ICVS Team



*Other contributors: Tong Zhu, Lihang Zhou, Mitch Goldberg, Arron Layns, Alexander Ignatov, Xinjia Zhou, Ryan Smith, Lori Brown, Tom Atkins, and STAR SDR/EDR teams

Outline

- **ICVS Team Members**
- **FY18 Accomplishments Highlight**
- **New ICVS Monitoring Capabilities Development**
  - Simultaneous Nadir Overpass (SNO) Intersensor Comparison
  - Double Difference (DD) Monitoring: $(O\text{-}B)_{sensor1}$ - $(O\text{-}B)_{sensor2}$
  - ICVS Clear/Sky Mask Machine-Learning Algorithm
  - ICVS Severe Event Watch (iSEW) System
- **Summary and Path Forward**

JPSS/STAR ICVS Team Members

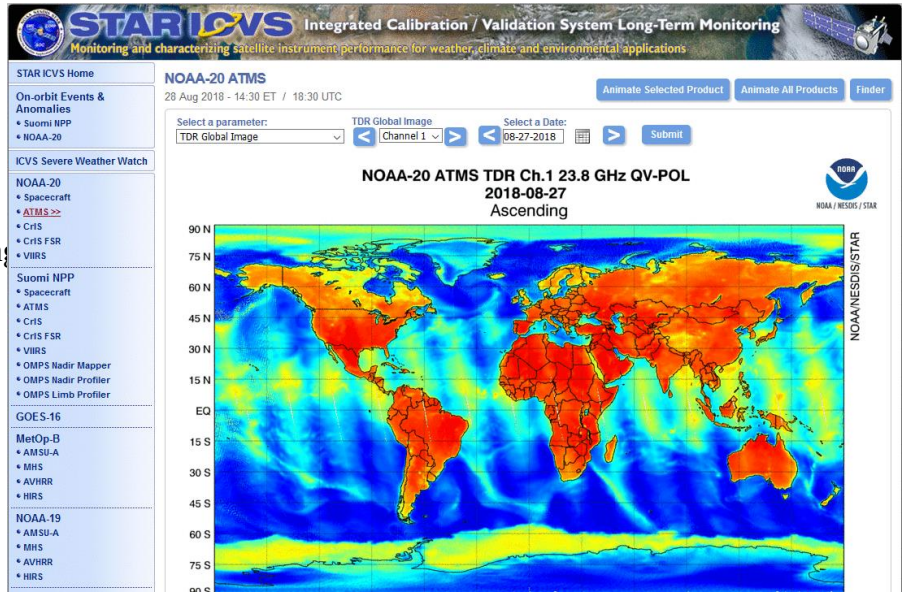
Name	Organization	Major Task
Banghua Yan (Gov. Lead,)	NOAA/STAR	ICVS science and development plan, technical oversight, project budget and schedule
Ninghai Sun (Tech. lead) (50%)	ProTech	ICVS system, **ATMS** ICVS software maintenance and development, inter-sensor comparison, and anomaly (technical) reports
Xingming Liang	ProTech	**VIIRS** ICVS software maintenance and development, VIIRS clear/sky mask algorithm/module, inter-sensor comparison, VIIRS O-B bias module, double difference module, and anomaly (technical) reports
Ding Liang	ProTech	**OMPS** ICVS software maintenance and development, inter-sensor comparison, cloud/clear detection module, O-B bias module, double difference module, **3D animation** of ATMS/VIIRS hurricane monitoring module, and anomaly (technical) reports,
Jingfeng Huang	ProTech	ICVS Severe Event[1] Watch (**iSEW**) System, **VIIRS** RGB module, **CrIS** O-B bias module, CrIS anomaly (technical) reports, and ICVS weekly report support
Xin Jin (50%)	ProTech	**CrIS** ICVS software maintenance and updates, inter-sensor comparison, double difference, and anomaly (technical) reports
Warren Porter	ProTech	**ATMS** inter-sensor comparison, double difference module, TDR/SDR **DCT-PLS** data smoothing processing module, **ICVS** system **upgrade**, and ICVS weekly report

[1] Events include but not limited to hurricane, volcano, fire, snow storm, dust storm, and other disaster events.

FY18 Top 5 Accomplishments

- **Successfully updated the ICVS for NOAA-20 (ATMS, CrIS, OMPS and VIIRS) to support NOAA-20 prelaunch, In-Orbit Verifications (IOVs) and postlaunch calval tasks**
  - Delivered NOAA-20 ICVS-Beta Modules to password-required users
  - Completed NOAA-20 spacecraft parameters monitoring
  - Developed CrIS full spectral resolution (FSR) SDR trending module
  - Added VIIRS high resolution imagery module
  - Developed new VIIRS SDR and GEO product quality monitoring module
  - Improved OMPS telemetry and other modules
- **Further developed new modules to support NOAA-20 instruments SDR provisional/validated reviews**
  - NOAA-20 ICVS-Beta Modules Transferred to Operation to ICVS website for public access
  - Developed ATMS SDR O-B angular dependent bias modules
  - Initialized CrIS O-B bias time series module
  - Initialized CrIS relative responsivity change module
  - Unified SNPP/NOAA-20 VIIRS imaging modules
  - Added VIIRS DNB analysis module for NOAA-20
  - Updated VIIRS H/F Factors trending module for NOAA-20
  - Fully functionalized NOAA-20 VIIRS TEB O-B biases monitoring
  - Initialized OMPS NM Reflectivity O-B monitoring code
- **Successfully delivered the first version of NOAA-20 ICVS packages to GRAVITE (Ceased on August 7, 2018)**
- **Completed the beta version of ICVS documents**
  - ICVS SNPP instrument technical reports
  - ICVS maintenance manual and ICVS User manual
- **Provided Customer/User-oriented Support**
  - Added "SNPP" and "NOAA-20" On-orbit Events & Anomalies Tables, Weekly/Monthly Reports

Welcome ICVS



Refer to ICVS: https://www.star.nesdis.noaa.gov/icvs/

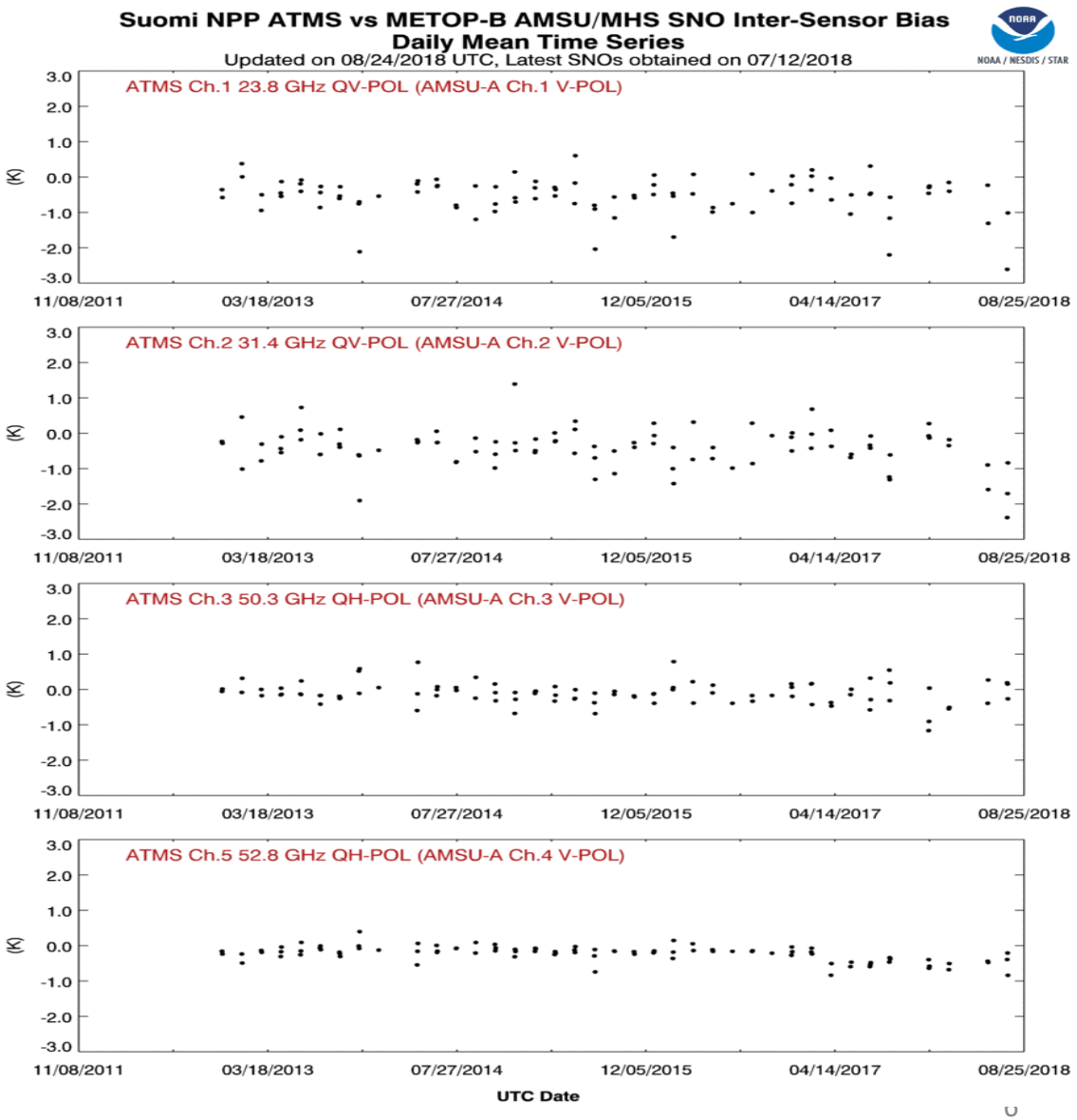
New ICVS Monitoring Capabilities Development

- **Objectives**
  - Provide on-orbit quantitative assessment of SNPP/NOAA-20 antenna (brightness) temperatures quality for user communities within and outside NOAA
  - Provide timely satellite observation information directly from multi-sensors SDR data in closely observing USA and global severe events (fire, hurricane, dust storm, snow storm, etc.) affecting public safety
    - Facilitate JPSS program office and NOAA line-office decision making
    - Assist SDR and EDR product developers and users in better validating product quality

- **New Advanced ICVS Monitoring Capabilities, e.g.,**
  - ATMS/AMSU-A Simultaneous Nadir Overpass (SNO) Intersensor Comparison Monitoring
  - VIIRS Double Difference: (O-B)NOAA-20 - (O-B)SNPP
  - ICVS Cloud Mask Machine-Learning Algorithm
  - ICVS Severe Event Watch (iSEW) System
    - 9 experimental VIIRS RGB combination imaging products
    - DCT-PLS Smooth algorithm for gap-filling ATMS observations
    - 3D ATMS/VIIRS animation for hurricane monitoring

ICVS Simultaneous Nadir Overpass (SNO) Intersensor Comparison: Preliminary Results

- Planned ICVS-SNO Intersensor Comparison Activities:
  - ATMS/AMSU-A/MHS
  - VIIRS/ABI
  - CrIS/VIIRS
  - OMPS/GOME-2
- Preliminary results: life-time monitoring of SNPP ATMS and Meop-A/B and NOAA-19 AMSU-A/MHS SNO intersensor comparisons
  - ATMS Ch. 1 to 15 except Ch. 4 vs. AMSU-A Ch. 1 to 14
  - ATMS Ch. 18, 20, 22 vs. MHS Ch. 5 to 3
  - ATMS Ch. 16 (88.20 GHz) vs. MHS Ch. 1 (89 GHz)
  - ATMS Ch. 17 (165 GHz) vs. MHS Ch. 2 (157 GHz)



(Reference: https://www.star.nesdis.noaa.gov/icvs/status_NPP_ATMS.php)

Brightness Temperature Double Difference (DD): Preliminary Results (1)

- **DD Calculation:**

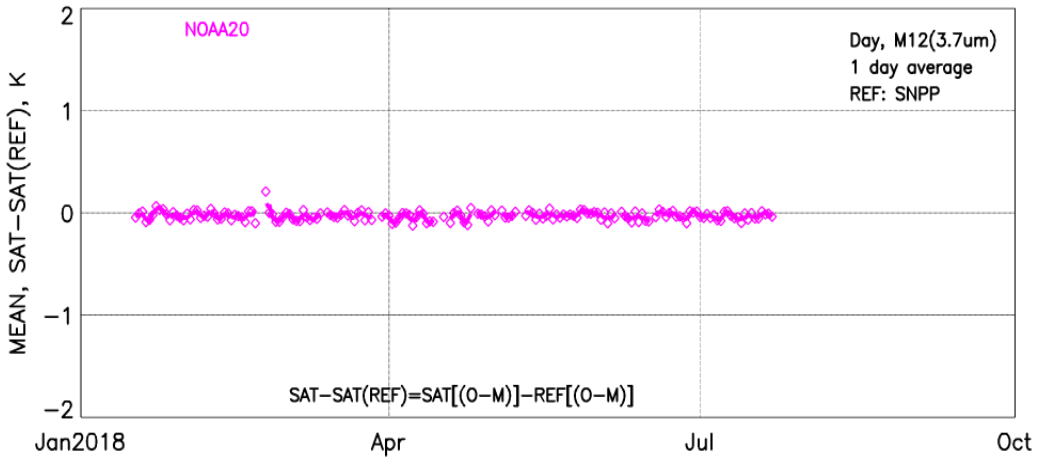
  DD = NOAA-20 (O-B) – SNPP (O-B)

  O: Satellite observations

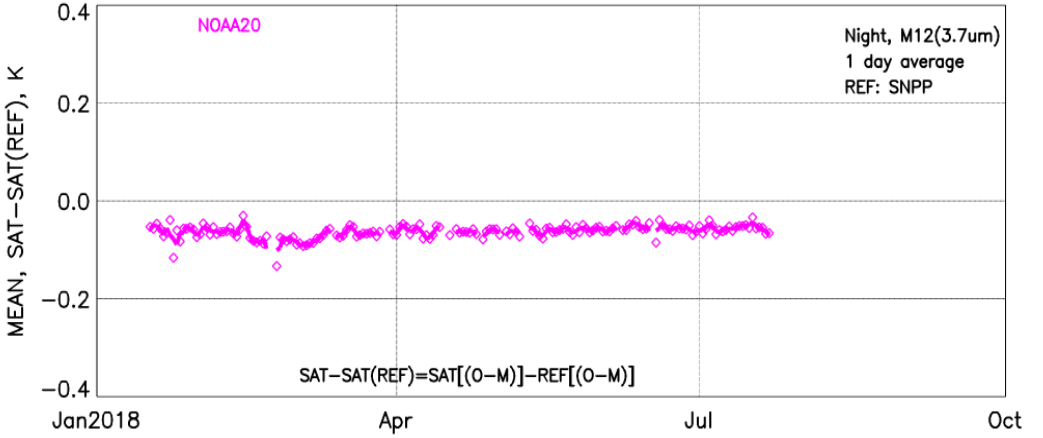
  B: CRTM simulations using ECMWF ancillary data of atmospheric profile and surface properties

  Purpose: Mostly cancel biases and uncertainties in used radiative transfer model and atmospheric profiles ; Reproduce more accurately the difference between NOAA-20 and SNPP sensor TDR/SDR data

Day Time



Night Time



- **Preliminary Results: VIIRS TEBs from M12 through M16**
  - M12: 0.003 K (Day) and -0.05 K (Night)
  - M13: -0.03 K (Day) and -0.02 K (Night)
  - M14: 0.11 K (Day) and 0.12 K (Night)
  - M15: 0.04 K (Day) and 0.03 K (Night)
  - M16: 0.05 K (Day) and 0.04 K (Night)

(Will add to ICVS web site soon)

Brightness Temperature Double Difference (DD): Preliminary Results (2)

- **DD Calculation:**

  DD = NOAA-20 (O-B) – SNPP (O-B)

  O: Satellite observations

  B: CRTM simulations using ECMWF ancillary data of atmospheric profile and surface properties

  Purpose: Mostly cancel biases and uncertainties in used radiative transfer model and atmospheric profiles ; Reproduce more accurately the difference between NOAA-20 and SNPP sensor TDR/SDR data

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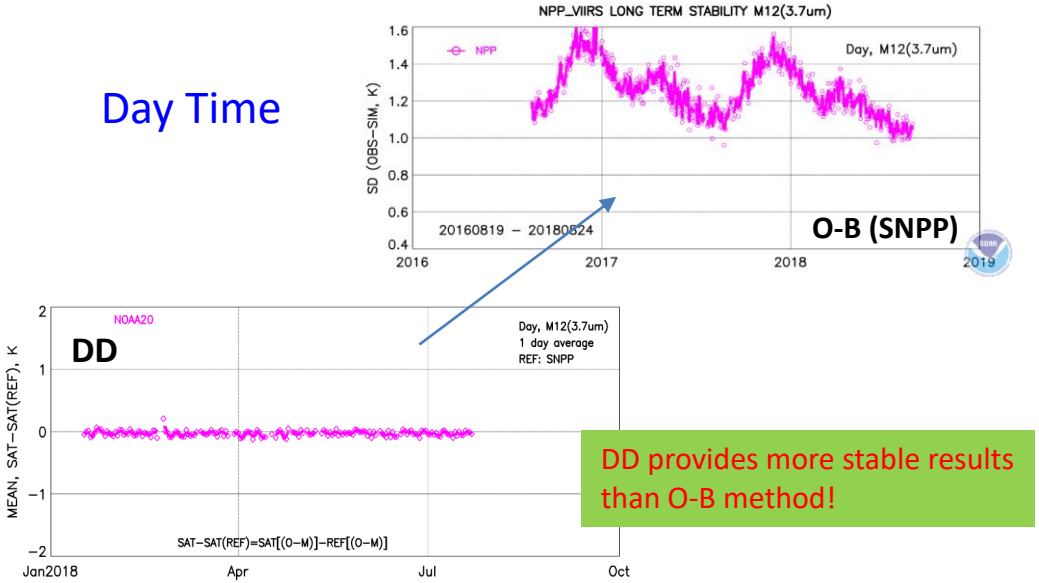
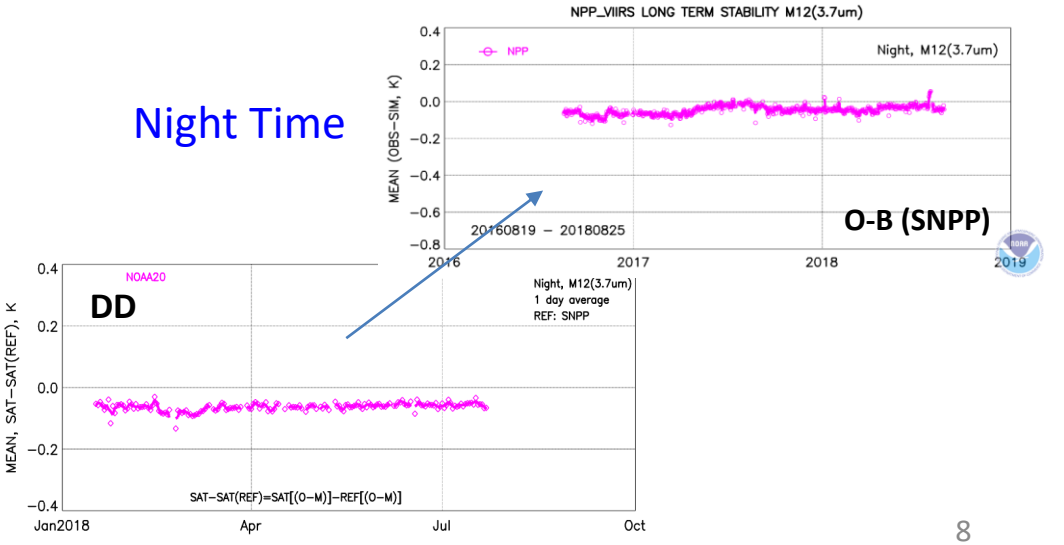
  - M16: 0.05 K (Day) and 0.04 K (Night)

Day Time



DD provides more stable results than O-B method!

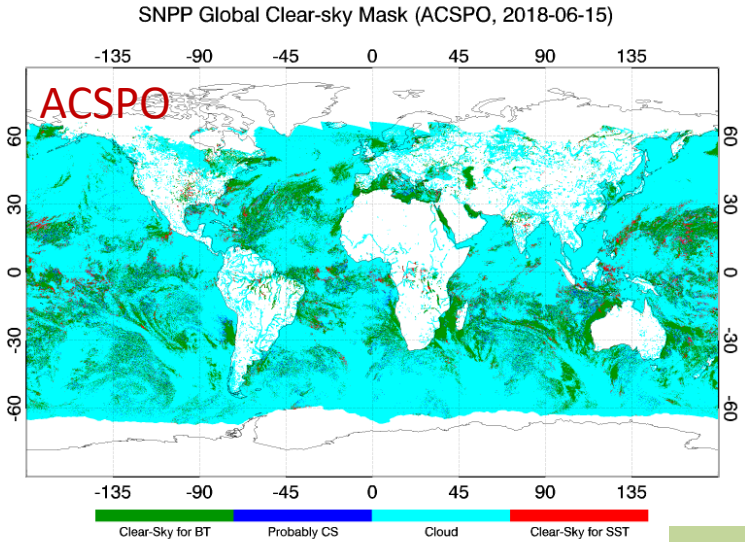
Night Time



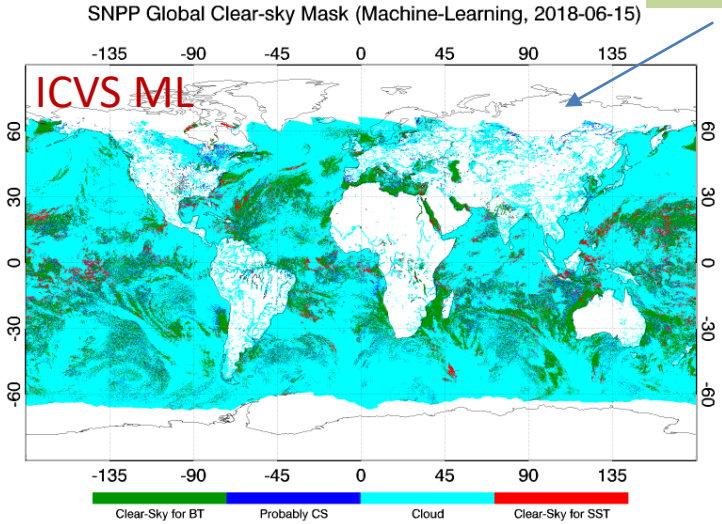
(Will add to ICVS web site soon)

Machine Learning Clear/Sky Mask (CSM) Algorithm for ICVS VIIRS: Preliminary Results

- **Background/Objective**
  - The existing ICVS CSM is a sensor-specific and not available for SDR Cal/Val immediately after launch
  - Develop a fast, platform-independent VIIRS-based CSM for ICVS
- **Machine Learning Algorithm**
  - **Training Data Set**: STAR Advanced Clear-Sky Processor for Ocean (ACSPO) SST system (A. Ignatov et al.)
  - **Inputs**: observed and simulated radiance data at bands 12, 15 and 16; satellite view zenith and solar zenith angles; regress and model SST; spatial variance
  - **Outputs:** clear sky (CS) for BT and SST, probable clear sky, and cloud



The retrieved ML CSM is about 94-98% match ACSPO.



Refer to the poster about "**A Machine Learning-Trained ICVS VIIRS Clear-Sky Mask Algorithm Applicable for Multiple Satellites**" by Liang et al.)

ICVS Severe Event Watch (iSEW) System

- **Objective:**
  - provides a timely and unique information about severe events closely linked to public safety by combining multi-sensors of SNPP/JPSS SDR observations
- **ICVS Severe Event Watch (iSEW) to innovatively use multi-sensor SDRs**
  - Nine experimental VIIRS RGB combinations imaging products for severe events monitoring
  - Gap-filling ATMS observations with limb correction for hurricane monitoring monitoring
  - 3D ATMS/VIIRS animation for hurricane warm core structure monitoring

Benefits:

- Provide valuable JPSS satellite observations to facilitate decision making
- Provide creative ideas in advancing new technologies and developing new algorithms from multiple sensor SDR data
- Assist SDR and EDR product developers and users in better validating product quality

iSEW: 9 ICVS Experimental RGB Combination Imaging Products for Severe Event Monitoring

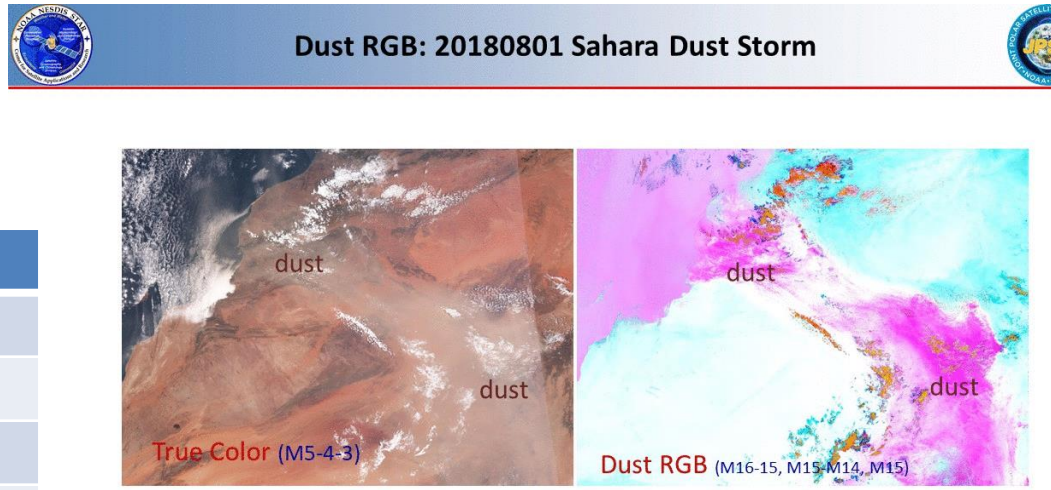
ICVS Nine Experimental RGB Combination Imaging Products

	R	G	B
True Color	M5	M4	M3
Nature Color (M)	M10	M7	M5
Nature Color (I)	I3	I2	I1
Dust*	M16-M15	M15-M14	M15
Snow/Cloud	M3	M10	M11
Fire Temperature	M12	M11	M10
DNB+M15	DNB	DNB	M15
Nature Fire Color	I4	I2	I1
Nature Color #2	M11	M7	M5

- Dust RGB combination is referred to NASA SPORT link: https://weather.msfc.nasa.gov/sport/jpsspg/rgb.html

(Refer to the poster about **"JPSS/STAR ICVS Severe Event Watch (iSEW) System Development and Applications**" by Huang et al.)

Examples: RGB combinations imaging



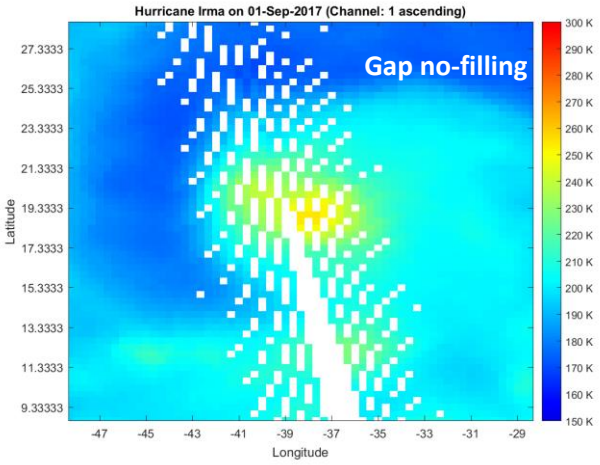
Evolution of Mendocino Complex Fire using Fire RGB Image (07/26 through 08/27, 2018)

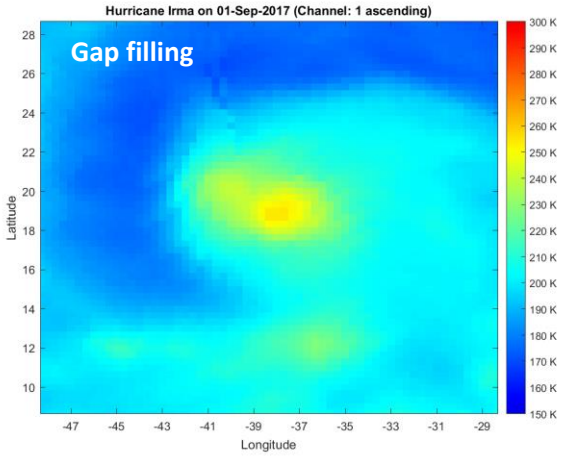
The Mendocino Complex Fire started on July 27 is the largest recorded fire complex in California history

iSEW: Gap-Filling ATMS Observations for Hurricane Monitoring

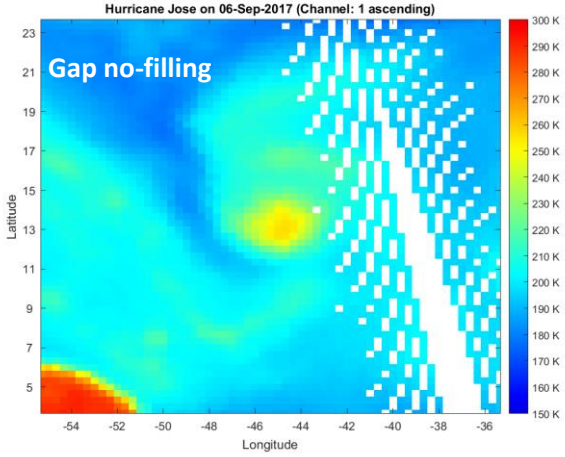
- Gap-filling method:
  - Garcia Discrete Cosine Transform (DCT)-Penalized Least Squares (PLS) (D. Garcia 2009)
- Uncertainty upon 33 cases analyses:
  - Errors are no more than 1 Kevin for temperature sounding channels
  - Errors are less than a few Kelvin for window and water vapor sounding channels amounted
- The gap-filling method has been applied to all hurricane cases influencing USA in 2017/2018 (here are two examples)

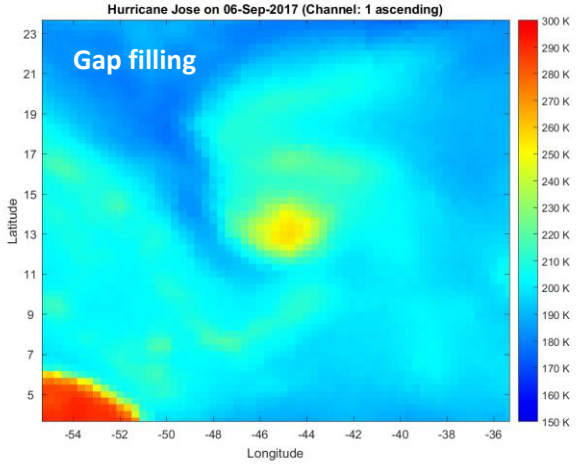
Examples: **Hurricane Irma (Aug. 31, 2017)**





Hurricane Jose (Sept. 5, 2017)



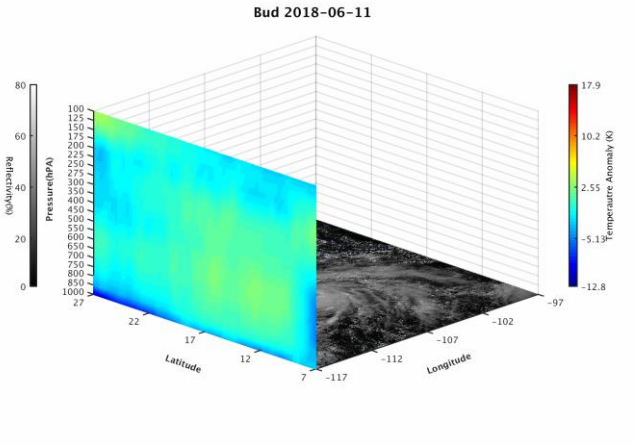


Refer to the poster with "**Application of a 2D DCT-PLS Smoothing Algorithm for ICVS Hurricane Event Watch**" by Porter et al.

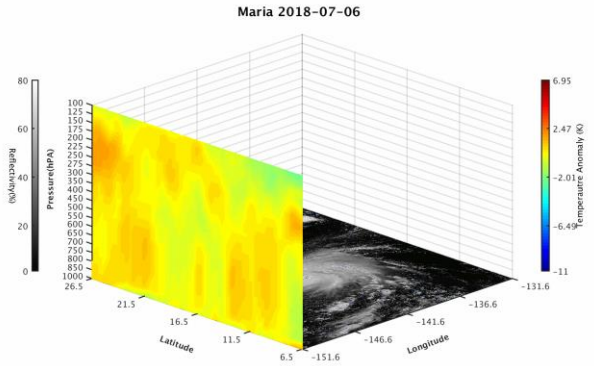
iSEW: 3D ATMS/VIIRS Animation Monitoring of Hurricane Warm Core Structure

- 3D animation image consists of 21 pressure levels of temperature profile information and VIIRS I1 band (0.64 μm) as backgrounc in the bottom and
- Brightness temperatures are <u>limb-corrected ATMS</u> observations from channels 1 to 15 (Zhang et al. 2017)
- <u>Temperature anomaly</u> at 21 pressure levels from 1000 hPA to 100 hPA are retrieved from ATMS brightness temperature observations from channels 5 to 12 (Zhu and Weng 2013)
- <u>Data gaps are filled</u> by 2-D spline smoothing algorithm (refer to W. Porter et al.'s poster)
- 3D animation is made of slices of hurricane volume along latitude, longitude, altitude direction and around center

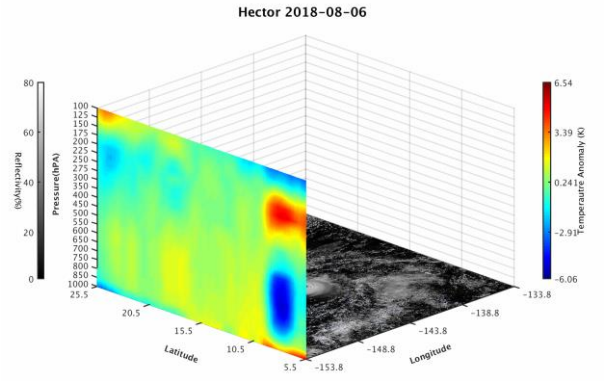
Hurricane Bud (June 11)



Hurricane Maria (July 06)



Hurricane Hector (Aug. 06)



Hurricane Lane (Aug. 21)

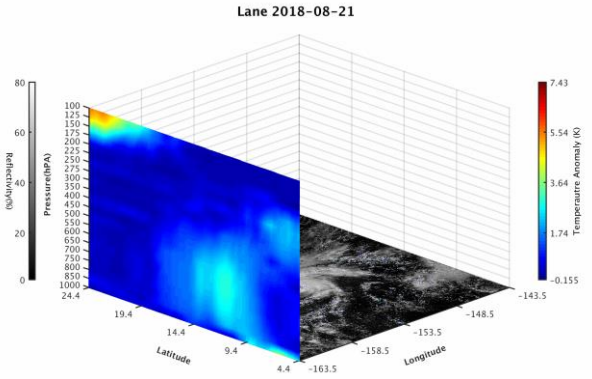


Figure Four hurricane cases: typically, warm anomaly was detected in the upper level though cold temperature anomalies occurred in the lower level of hurricane center (Refer to the poster about "Hurricane Structure 3D Animation Demo at STAR ICVS" Liang et al.)

(Curtesy of T. Zhu and L. Zhou for providing algorithm code and/or valuable suggestions as well W. Chun and F. Weng for their legacy effort)

Summary

- The ICVS has provided successfully a significant and timely technical support to JPSS NOAA-20 instrument on-orbit Cal./Val. and SDR/EDR Reviews
- The ICVS is being updated to provide more valuable information of SDR data quality and severe events (e.g., hurricane, fire, dust storm, and snow storm) for SDR/EDR teams, JPSS program office, STAR managements, and other users.
  - ATMS/AMSU-A/MHS SNO Intersensor Comparison
  - VIIRS TEBs DD Monitoring
  - ICVS VIIRS CSM Machine-Learning Algorithm
  - ICVS Severe Event Watch (iSEW) System

Quality, Technology and Science are the essential of the ICVS!

Path Forward

- **Continue to advance the quality, technology and science of the ICVS system to support SDR/EDR teams, JPSS program and NOAA Users needs, e.g.,**
  - SNPP/NOAA-20 instrument SDR data quality modules (e.g., O-B)
  - SNPP/JPSS1 cross-sensor SDR data comparison monitoring package (e.g., SNO and DD)
  - A fast, platform-independent CSM for ICVS multiple sensors
  - ICVS SNPP/JPSS1 SDR iSEW system
  - SNPP/JPSS1 geolocation accuracy trending package
- **Upgrade to a new generation ICVS Monitoring System to improve the quality, efficiency, and timeliness of the system**
  - Improve the ICVS monitoring timeliness and latency performance
  - Improve ICVS Interactive capability
  - Conduct a user survey to collect new needs/feedback from users to enhance the ICVS capabilities
- **Assist STAR SRD/EDR teams in preparation of J2 prelaunch test**